SOIL SURVEY OF THE YUMA AREA, ARIZONA.

By J. GARNETT HOLMES.

LOCATION AND BOUNDARIES OF THE AREA.

The part of the Colorado River Valley covered by this survey occupies the extreme southwestern corner of Arizona. The area is a long, narrow strip beginning at the town of Yuma and extending southwest along the Colorado River. It is bounded on the east and south by a bluff or river terrace from 40 to 75 feet high that separates the bottom lands from a high, level mesa. This mesa is cut by the

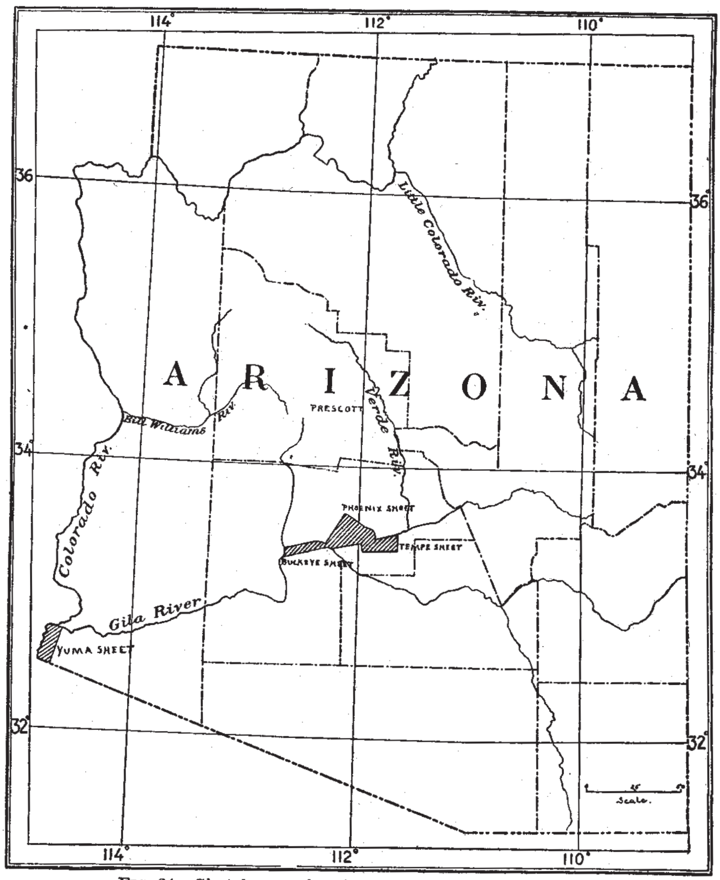

FIG. 24.—Sketch map showing areas surveyed in Arizona.

river at Yuma and comes to within a mile of the river just south of the limits of the survey. Across the river to the northward is the State of California, and west of the river where it flows nearly south is Lower California, a Territory of the Republic of Mexico. The area comprises in all about 100 square miles, or 63,469 acres. (See fig. 24.)

HISTORY OF SETTLEMENT AND AGRICULTURAL DEVELOPMENT.

Nearly all the area mapped was originally included in what was known as "Algodone's grant," the title to which antedated the Gadsden purchase, by which this district first became a part of the territory of the United States. There was, however, a strip of land along the foot of the mesa that was never claimed as a part of the grant. Prior to 1891 there was no cultivation of crops in the area, except in a very limited way by Indians and Mexicans on the overflow lands. At this time desert filings were made upon the lands along the mesa outside the grant by those interested in the grant and by a few bona fide settlers. Shortly afterwards a ditch was constructed for irrigation. This was the first organized, well-directed attempt at agriculture. Only the higher portions of the delta were irrigated, and as water could not readily be brought onto the land by gravitation it was lifted by pumping. It was necessary to raise the water from 7 to 15 feet, according to the stage of water in the river. This first ditch afterwards passed into the hands of Eugene Ives and others, and is now known as the Ives Pump Ditch. It is said to divert 3,000 miner's inches. This pumped water is very expensive, costing annually from $7 to $20 per acre, according to the amount of water used.

The next effort at irrigation was near Somerton, about 13 miles southwest of Yuma, where in 1895 J. I. Toler and several others formed a company, sunk several artesian wells, and put in quite an extensive pumping plant. The water-bearing sands, though near the surface, were of too fine texture to allow the water to flow through them rapidly enough to supply the pumps, and the work was abandoned without any land being reclaimed.

In 1897 a few settlers on the Government lands and squatters on the grant in sections 9 to 16 and on adjoining sections in T. 10 S., R. 24 W., associated for the purpose of taking water from the river by means of a gravity canal, through what is known as the American Slough, with a capacity for irrigating 10,000 acres. This system was to be known as the American Canal. In 1899 the original company was absorbed by the Colorado Valley Canal and Levee Company, which did very little work. When, in 1900, the Ludey Canal was being constructed, this canal, with all works and rights, was purchased and became a part of the Ludey system. Although it was and is still the purpose of the American Canal to irrigate 10,000 acres of the overflow lands southwest of Somerton, only about 100 acres have as yet been irrigated. The annual overflow of the Colorado River has greatly damaged the canal as well as the crops. The river will have to be effectually leveed before cultivation can be profitable in this section.

In 1898 a few settlers and squatters in the vicinity of Yuma constructed the Farmers' Mutual Pump Ditch, with head works close to

those of the Ives Pump Ditch. It is the intention to use water from this ditch to irrigate lands too high for gravity irrigation. The lift is the same as for the Ives Ditch, and consequently the expense for irrigation is about the same, ranging from $7 to $20 an acre per year.

In the same year (1898) there was begun the Farmers' Mutual Gravity Ditch, designed to irrigate 40,000 acres of land in the valley. Work upon this ditch progressed rather slowly, so that it was not until early in 1901 that water was turned into it. Only a small amount of irrigation was done from this ditch, however, for when the June high water subsided the ditch had so filled with sediment that its bottom was above the water level of the river, and as no machinery for cleaning the canal had been provided another long delay was experienced. At the present time (February, 1902) a dredge is being built which is expected to keep the canal free from silt, and the early beginning of permanent irrigation from this ditch is confidently predicted. The keeping of irrigation ditches free from silt is yet an unsolved problem and is, perhaps, the greatest engineering difficulty now confronting the irrigators of lands anywhere along the lower reaches of the Colorado River.

In 1900 the Ludey Canal was begun. It covers practically the same territory in the United States as the Farmers' Mutual, but with the addition of more land farther south in Mexico. The system is planned to irrigate 100,000 acres in all. The first water was run into this canal in 1901, and the same difficulty was experienced as in the case of the Farmers' Gravity Ditch, the head of the canal becoming filled with silt. A hydraulic dredge is now working on the canal, and no doubt water will soon be available for irrigation. The canal has not yet been built to the international boundary line, and success of irrigation with the part already constructed will determine whether or not such extension will be made.

By far the greater part of the valley was originally claimed by the Algodone Grant Company. Squatters came in and settled on the property, and the matter was taken to the courts. After being in litigation for several years the issue was finally decided by the Supreme Court, in 1900, in favor of the squatters. This threw the entire valley open for settlement as Government land. Locations were rapidly made, until now the entire valley has been filed upon, either under the desert or the homestead act.

Several hundred acres of alfalfa have been successfully cultivated in that part of the valley not included in the grant and in some areas within the grant under the two ditches supplied by pumps. Quite a number of farmers are entirely supported from the revenue thus derived from the land. Beyond this there is as yet very little cultivation. Most of the hay is sold in the local market. Very little is marketed in the form of secondary products. The greater number of

the settlers live in brush and log houses plastered with mud and having dirt roofs. Agriculture is yet in its infancy.

CLIMATE.

The Yuma area is in an extremely arid belt. The rainfall is not only very light, but is also very irregular, so that irrigation alone has to furnish moisture for all kinds of vegetation. The summer is long and very hot, while the winter can hardly be called such at all. The maximum daily temperature in summer ranges from 112° to 120° for weeks at a time, although the nights are usually cool enough to be comfortable. The winter nights are quite cold, ice often forming, but the days are most delightful. Very seldom is a cloud seen. Many of the people live almost entirely out-of-doors and suffer very little discomfort on account of the weather.

Appended is a table compiled from records of the Weather Bureau, showing the temperature and rainfall at Yuma. No other station is situated in the area surveyed.

Normal monthly and annual temperature and precipitation.

Month.	Yuma.		Month.	Yuma.	
	Temperature.	Precipitation.		Temperature.	Precipitation.
	° F.	*Inches.*		*° F.*	*Inches.*
January	53.9	0.42	August	91.6	0.35
February	59.0	.51	September	84.2	.15
March	65.1	.26	October	72.5	.28
April	70.5	.07	November	62.7	.29
May	77.8	.04	December	57.3	.46
June	84.8	.00	Year	72.6	2.97
July	91.5	.14			

PHYSIOGRAPHY AND GEOLOGY.

The valley as a whole is a plain gently sloping to the southwest, broken only by the local occurrence of sand dunes, gullies, lagoons, or old river beds. These minor departures from grade interfere with agriculture chiefly in that they make preparation for irrigation expensive. In some places, as in the areas where sand dunes are mapped, economical cultivation is at present impracticable, but most of the land requires very little leveling to prepare it for irrigation.

This area forms a part of the eastern upper end of the Colorado River delta. The entire valley is made up of sediments, and consists of a great bed of sand, overlain and interstratified with layers of finer material, left by the river as it shifted its course from one side of the valley to the other. The soils are not directly traceable to the rock whence they were derived, as the Colorado drains an immense

area and has a great number of tributaries, any one of which may be chiefly responsible, at different seasons, for the sediment carried by this lower part of the stream. About 75 per cent of the lands of the valley are overflowed and a layer of sediment added to the soil each year. The deposition has been much greater near the present stream bed than farther back, so that the lands immediately bordering the stream are higher and covered by only a few inches of water during the flood season, while those farther back may in places stand under 7 or 8 feet of water. (See Pl. LIV.)

SOILS.

The soils of the valley have a common origin, and therefore differ mainly in texture. As a result principally of this difference in texture the soils are now found to contain widely varying amounts of soluble mineral matter and humus. All of the soils, even the heaviest, are underlain at a few feet by sand, which extends to unknown depths. This sand is in places quite coarse, but the greater part is very fine and of the nature of quicksand. When this very fine sand is found on the surface, it forms the fine sandy loam.

The following five types of soil were recognized, the areas of which are outlined on the accompanying map: Imperial sand, Imperial sandy loam, Gila fine sandy loam, Santiago silt loam, and Imperial loam. The area of each of these in acres and the proportion each forms of the total area are brought out in the following table:

Areas of different soils.

Soil.	Acres.	Per cent.
Imperial loam	20,800	32.8
Gila fine sandy loam	17,038	26.8
Imperial sandy loam	12,806	20.2
Imperial sand	9,062	14.3
Santiago silt loam	3,763	5.9
Total	63,469	....

IMPERIAL SAND.

The Imperial sand occupies about 14 square miles, or 14.3 per cent of the total area surveyed. It is found skirting the sandy mesa and in isolated areas throughout that part of the valley that is not subjected to overflow. Excepting the dunesand phase of this soil, the surface is comparatively level. Along the mesa the soil is formed directly by the wearing down of the mesa, the sand as the coarser product of weathering being deposited along its base. The other areas are of river sand that, unlike the same material over the greater part of the valley, has no covering of finer sediment deposited upon it. Every rainfall of any extent adds to the sand soil along the mesa, showing plainly its process of formation.

The Imperial sand is a loose, incoherent reddish-brown sand. Along the mesa it is in places not more than 3 or 4 feet deep, underlain by a sandy loam; the sandy loam subsoil representing the soil that was formed by the admixture of sand from the mesa and loam from the river when the overflow reached the base of the mesa. The sand has since been deposited upon this sandy loam. The action of the wind has transformed large areas of this valuable sand soil into dune lands, with sand dunes often from 5 to 20 feet high.

The cost of leveling such land, with level land at the present prices, would not pay, and the development of these rougher areas will naturally be postponed until the more level areas have been brought under cultivation and values have risen to a point that will warrant the investment of the considerable amount of money necessary to fit the soil for irrigation.

Alfalfa is the only crop that has been grown commercially upon this soil, although it is an admirable soil for the growth of truck crops, such as sweet potatoes, melons, onions, etc. Like most sandy soils, it is well drained and free from alkali.

The following mechanical analyses show the texture of this type of soil:

Mechanical analyses of Imperial sand.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6507	Center S. side No. 15-40, sec. 1, T. 9 S., R. 24 W.	Sand, 0 to 60 inches.	0.31	Tr.	0.77	0.83	61.64	27.76	6.77	2.23
6506	SE. corner No. 14-40, sec. 18, T. 9 S., R. 23 W.	Sand, 0 to 48 inches.	.26	Tr.	.29	1.26	35.20	43.00	16.15	4.15

IMPERIAL SANDY LOAM.

The Imperial sandy loam, like the Imperial sand, is situated principally in the part of the valley not at present subject to overflow. The surface of this soil is usually comparatively level, requiring very little work to prepare it for irrigation. It has been formed by the admixture of sediment from the river with coarser material transported from the higher land surrounding the valley.

This soil is a loose, friable brown sandy loam of good texture, easy to cultivate, and requiring little cultivation to maintain good tilth. It is usually underlain by sand at a depth of from 3 to 4 feet. In

some places, however, 2 or 3 feet of loam intervene between the soil and the sand subsoil.

The water table of the entire valley is high, being on an average but 10 feet below the surface, and this soil, owing to a high capillary power, has in places accumulated considerable alkali. Not only has the soil a high capillary power, but water moves through it quickly, making the total amount of water evaporated from its surface quite large. For these reasons, if the soil is left uncultivated the accumulation of alkali is rapid, but under cultivation with irrigation the accumulation is avoided by the presence of the surface mulch and the ready leaching out of the salts.

Alfalfa, sorghum, barley, and kindred field crops are the only ones that have as yet been grown to any extent on this soil. (See Pl. LVI.)

The following table gives the mechanical analyses of this soil type:

Mechanical analyses of Imperial sandy loam.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6509	NW. corner No. 1-40, sec. 26, T. 8 S., R. 24 W.	Sandy loam, 0 to 72 inches.	0.77	0.00	0.08	0.21	1.48	15.90	76.00	6.30
6508	Center S. side sec. 20, T. 8 S., R. 23 W.	Sandy loam, 0 to 60 inches.	.67	.00	.00	.32	1.37	17.40	67.50	13.42
6511	E. side No. 9-40, sec. 12, T. 9 S., R. 24 W.	Sandy loam, 0 to 72 inches.	.38	.00	Tr.	.42	1.57	12.98	69.20	15.80
6510	Center W. side sec. 20, T. 9 S., R. 23 W.	Sand, 36 to 72 inches.	.11	.00	.10	.71	45.75	35.09	14.87	3.46
6512	W. side No. 13-40, sec. 36, T. 9 S., R. 24 W.	Clay, 36 to 72 inches.	.63	Tr.	.26	.43	1.55	3.28	50.43	44.12

GILA FINE SANDY LOAM.

The Gila fine sandy loam is found in a long, narrow strip skirting the river, and in other parallel strips which probably represent the margins of former river courses. The surface is level and usually covered with a dense growth of arrow weed, willows, etc. This soil is formed of the particles of sediment first deposited by the overflow water, the finer particles of silt and clay being carried farther inland or downstream and deposited in stiller water.

The Gila fine sandy loam is a fine sand having the properties of a sandy loam. The particles are nearly all of uniform size, making a soil of high capillary power and one through which water not only moves long distances but also with great rapidity. It is easily culti-

vated and remains in good tilth for a long time. The surface soil is from 3 to 20 feet deep and is underlain by a coarser river sand.

Owing to its high capillary power and the nearness of the water table to the surface over most of the areas of this soil, the greatest care must be taken to prevent the rise of alkali after the removal of the natural vegetation. With proper care, however, it should be one of the most productive soils of the valley.

Crops of almost any kind suited to the climate do exceptionally well on this soil. Alfalfa is the principal crop grown. Very little of this soil is at present under cultivation.

The following table gives mechanical analyses of this type of soil:

Mechanical analyses of Gila fine sandy loam.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6500	N. side sec. 33.......	Fine sandy loam, 0 to 36 inches.	0.63	0.00	Tr.	0.13	8.04	43.00	44.06	4.34
6501	SW. corner No. 2–40, sec. 25, T. 8 S., R. 24 W.	Fine sandy loam, 0 to 72 inches.	.54	.00	0.10	10	3.36	38.70	51.50	6.27

SANTIAGO SILT LOAM.

Like nearly all the other soils of the valley, the Santiago silt loam is composed of deposits laid down by the Colorado River. It differs from the Gila fine sandy loam only in that the particles of soil are finer, being the intermediary soil between the Gila fine sandy loam and the Imperial loam. It is well decomposed, contains much organic matter, and is very rich in plant food. The surface covering of grayish to dark-brown friable silt loam has a depth of from 18 to 30 inches and is underlain by fine sandy loam or sand. Taking into consideration the shifting nature of the river and the fact that all the overflow lands are constantly subjected to change, the existence of areas of this and other soils in the overflow part of the valley may not be at all permanent. A few years of deposition of loam or sand, caused by a change in the bed of the river, would be sufficient to obliterate present soil boundaries and necessitate reclassification.

Only about 6 square miles of the Santiago silt loam were found in the valley, the occurrence of the type, as shown on the map, being limited to a small district in the neighborhood of the large bend in the river. This soil has a level surface and in its natural condition is

ered with wild hemp, arrow weed, annual grasses, and willows. A small proportion of the Santiago silt loam contains injurious amounts of alkali and nearly all contains at least a small amount.

None of this soil is now cultivated, but experience with like soil in other regions has shown it to be well suited to all common field crops, as well as to some special crops. It is on a similar soil in Orange County, Cal., that most of the celery produced in that county is grown,[a] while it is one of the most important bean soils of Ventura County, in the same State.[b]

The following table shows the texture of this type of soil:

Mechanical analyses of Santiago silt loam.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6514	SW. corner sec. 31, T. 9 S., R. 24 W.	Silty loam, 0 to 24 inches.	2.17	Tr.	0.10	0.17	0.50	2.34	82.54	14.35
6513	W. side No. 5-40 sec. 6, T. 10 S., R. 24 W.	.....do	1.70	Tr.	.22	.22	.84	4.46	70.60	23.68

IMPERIAL LOAM.

The Imperial loam occupies by far the largest proportion of the area surveyed. Wherever the overflow water is comparatively still for any length of time this soil is deposited, and hence most of it is found as a covering for the other soils of the overflowed district. Its surface is comparatively level, except for the intersecting gullies and channels. Should the overflow area be protected by embankments, very little difficulty would be experienced in leveling the entire area of this soil for irrigation.

The Imperial loam is a sticky, plastic, chocolate-brown loam, composed of finely divided particles of mineral matter and a considerable proportion of organic matter. The surface soil ranges from 1 to 6 feet in depth and is underlain by a coarse to fine sand. Much of the soil that is not overflowed already contains an excessive amount of alkali, and wherever the soil is 5 feet or more in depth the greatest care must be exercised if future accumulation is to be prevented. It is the soil most liable to become alkaline under cultivation and irrigation.

[a] See Report on Field Operations, Bureau of Soils, U. S. Department of Agriculture, 1900.

[b] Ibid., 1901.

Some small areas of this soil lying above high water have been successfully cultivated to alfalfa, sorghum, and other field crops. The type is well adapted to the growing of wheat, corn, and alfalfa when cut for hay and not pastured. When used for pasture the soil packs very hard and the alfalfa is killed. At present the greater part of the area of this soil is overflowed annually and can not be cultivated with any certainty of success until this water is in some manner kept off.

The following table shows the texture of this type of soil:

Mechanical analyses of Imperial loam.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
6505	Along international boundary line.	Loam, 0 to 24 inches.	1.54	Tr.	0.17	0.17	3.48	17.90	56.90	21.35
6502	Center S. side No. 13-40 sec. 36, T. 8 S., R. 23 W.	Loam, 0 to 36 inches.	.10	Tr.	.19	.08	2.39	12.87	53.90	30.90
6504	Near center sec. 2, T. 9 S., R. 24 W.	.....do...............	.35	Tr.	.30	.25	1.96	8.65	57.20	31.65
6503	Subsoil of 6502......	Clay loam, 36 to 72 inches.	.72	Tr.	.11	.11	.86	7.79	58.63	32.50

ALKALI IN SOILS.

At the time that the soil survey of this area was made an alkali map was also prepared, showing the location and extent of areas of the different grades of alkali soil and the amount of alkali in the first 6 feet of soil. The map, which accompanies this report, shows by distinguishing colors the land which contains less than 0.20 per cent, from 0.20 to 0.40 per cent, from 0.40 to 0.60 per cent, from 0.60 to 1 per cent, from 1 to 3 per cent, and over 3 per cent of alkali. The boundary lines between these areas of different alkali intensities were carefully established by work in the field.

A reference to the alkali map will show, as has already been stated elsewhere, that the greater part of the alkali land is situated just above the high-water line of present overflow, where evaporation from the surface has taken place without any surface flooding, showing plainly that the alkali is the result of the evaporation of the river water. Other alkali areas are found along the foot of the bluff, being caused by a small amount of seepage from the high lands above.

Much of this alkali is found in very sandy or fine sandy loam. If proper drainage is maintained this land can be reclaimed by a few heavy surface floodings.

Appended are a number of chemical analyses of crust and soils from this area, made in the laboratories of the Bureau:

Chemical analyses of salts in alkali soils.

Constituents.	6501. SW. corner No. 2–40, sec. 25, T. 8 S., R. 24 W.; fine sandy loam, 0 to 72 inches.	6506. SE. corner No. 14–40, sec. 18, T 9 S., R. 23 W.; sand, 0 to 48 inches.	6504. Near center sec. 2, T. 9 S., R. 24 W.; loam, 0 to 36 inches.	6503. Under No. 6502; clay loam, 36 to 72 inches.	6509. NW. corner No. 1–40, sec. 26, T. 8 S., R. 24 W.; sandy loam, 0 to 72 inches.	6502. Center S. side No. 15–40, sec. 36, T. 8 S., R. 23 W.; loam, 0 to 36 inches.	6511. E. side No. 9–40, sec. 12, T. 9 S., R. 24 W.; sandy loam, 0 to 72 inches.	6517. Center N. side sec. 27, T. 8 S., R. 24 W.; alkali crust, 0 to 1 inch.
Ions:	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Calcium (Ca)	9.42	5.18	2.72	1.74	9.02	5.27	3.87	2.04
Magnesium (Mg)	2.53	.99	1.27	1.43	4.45	2.49	2.07	1.96
Sodium (Na)	11.23	24.54	27.80	29.25	17.66	25.03	29.29	32.04
Potassium (K)	11.60	4.38	4.17	3.97	3.34	3.58	1.14	2.10
Sulphuric acid (SO_4)	28.26	32.96	18.51	13.68	18.26	14.64	14.07	4.66
Chlorine (Cl)	21.74	22.39	35.73	41.35	43.93	46.36	47.60	56.98
Bicarbonic acid (HCO_3)	15.22	9.56	9.80	8.58	3.34	2.63	1.96	.22
Conventional combinations:								
Calcium sulphate ($CaSO_4$)	32.25	15.34	9.07	5.88	25.83	17.86	13.09	6.61
Magnesium sulphate ($MgSO_4$)	6.88	4.78	6.17	6.99	.00	.00	6.00	.00
Potassium chloride (KCl)	22.10	8.36	7.98	7.63	6.34	6.81	2.18	4.00
Sodium chloride (NaCl)	13.77	30.09	52.71	62.18	41.98	59.17	72.68	81.15
Sodium bicarbonate ($NaHCO_3$)	21.02	13.14	13.36	11.76	4.56	3.58	2.67	.28
Sodium sulphate (Na_2SO_4)	.00	28.29	10.71	5.56	.00	2.85	.00	.00
Calcium chloride ($CaCl_2$)	.00	.00	.00	.00	3.89	.00	.00	.25
Magnesium chloride ($MgCl_2$)	3.98	.00	.00	.00	17.40	9.73	3.88	7.71

Constituents.	6515. Center S. side sec. 20, T. 8 S., R. 23 W.; alkali crust and mulch, 0 to 1 inch.	6520. Center S. side No. 13–40, sec. 36, T. 8 S., R. 23 W.; alkali crust and mulch, 0 to 1 inch.	6516. NW. corner No. 1–40, sec. 26, T. 8 S., R. 24 W.; alkali crust, 0 to 1 inch.	6525. No. 6–40, sec. 9, T. 10 S., R. 24 W.; alkali crust, 0 to $\frac{1}{2}$ inch.	6526. No. 14–40, sec. 6, T. 10 S., R. 24 W.; alkali crust, 0 to $\frac{1}{2}$ inch.	6522. N. side sec. 33; alkali crust, 0 to 1 inch.	6519. No. 12 40, sec. 36, T. 8 S., R. 24 W.; alkali crust, 0 to $\frac{1}{4}$ inch.	6523. Center of sec. 17, T. 9 S., R. 23 W.; alkali crust, 0 to 1 inch.
Ions:	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Calcium (Ca)	6.56	8.78	5.70	2.35	0.92	1.55	.87	1.55
Magnesium (Mg)	2.67	3.39	6.76	.45	.28	1.00	.04	.25
Sodium (Na)	26.83	20.81	20.99	28.50	32.70	27.65	37.46	31.49
Potassium (K)	1.22	4.87	2.14	4.24	1.77	4.63	.88	6.50
Sulphuric acid (SO_4)	2.31	1.76	.87	41.82	37.73	20.75	10.64	5.31
Chlorine (Cl)	59.73	59.88	63.09	21.80	26.40	43.94	49.86	53.66
Bicarbonic acid (HCO_3)	.68	.51	.45	.64	.20	.48	.25	1.24
Conventional combinations:								
Calcium sulphate ($CaSO_4$)	3.25	2.50	1.23	7.98	3.14	5.26	2.97	5.28
Magnesium sulphate ($MgSO_4$)	.00	.00	.00	2.23	1.40	4.98	.36	1.27
Potassium chloride (KCl)	2.33	9.28	4.08	8.08	3.39	8.82	1.69	12.39
Sodium chloride (NaCl)	67.50	52.33	52.87	29.65	40.90	60.96	80.72	78.53
Sodium bicarbonate ($NaHCO_3$)	.93	.70	.61	1.15	.27	.66	.34	1.71
Sodium sulphate (Na_2SO_4)	.00	.00	.00	50.91	50.91	19.32	13.92	.82
Calcium chloride ($CaCl_2$)	15.48	21.90	14.70	.00	.00	.00	.00	.00
Magnesium chloride ($MgCl_2$)	10.51	13.29	26.51	.00	.00	.00	.00	.00

An examination of these analyses shows the alkali in this area to be white alkali, no sodium carbonate being present. In all cases there is an abundance of calcium sulphate ($CaSO_4$), which is seldom if ever found associated with harmful amounts of sodium carbonate (Na_2CO_3). The principal salts present are the chlorides of sodium, calcium, potassium, and magnesium. Only in a few localities are there more of the sulphates than of the chlorides. Sodium chloride (common salt) constitutes on an average nearly 60 per cent of the soluble matter present. When sufficiently concentrated this salt is extremely harmful to plants, 0.60 per cent being sufficient to kill ordinary crops. The other salts present are all harmful when present in sufficient concentration, except the gypsum ($CaSO_4+2H_2O$), which is only slightly soluble in pure water, so that if it alone were present not enough would go into solution to injure plants. On the other hand, when a comparatively strong solution of sodium, magnesium, or potassium chloride or carbonate, or any mixture of them, is brought into the presence of gypsum the latter becomes quite soluble. In this case, however, instead of increasing it decreases the harmful effect of the solution upon plant life. This fact has been demonstrated in the laboratory and has often been observed in the field, although the explanation for it is yet obscure.

It is on the loam soil of the valley, where the heavy soil extends below the level of the ground water, that especial care must be exercised to get rid of the alkali now accumulated and to prevent further accumulation of these salts. This soil is heavy, sticky, and plastic, and is but slowly pervious to water. It is therefore very difficult to remove the salts by leaching. Every available means should be used to make the texture of these soils more open. Stubble should be plowed under, and all the trashy barnyard manure available should be applied. The plowing under of this trash produces two results—is beneficial to alkaline lands in two ways: Not only does it improve the natural drainage of the soil, but it also aids in preventing evaporation, which is a very important consideration in the attempted reclamation of alkali lands.

AGRICULTURAL METHODS.

In that part of the valley situated above the overflow line farming will be comparatively simple. The same crops may be grown and the same methods of cultivation and irrigation used as in other parts of the Territory. Already alfalfa, the chief crop of the Territory, has been grown with reasonable profit. For this part of the valley the usual problems of proper cultivation and methods of application of water in irrigation are the things chiefly to be studied. The soils are mostly sandy, making the maintenance of good tilth a comparatively easy matter. Such soils, however, where the water table is near

enough to permit capillarity to bring water to the surface, there to be evaporated in great quantity, as is the case in this dry, superheated region, if left uncultivated soon become alkaline, even when the water contains only a small amount of soluble matter. Such a condition has already arisen in the soil areas contiguous to the part of the valley subject to annual overflow. The whole valley being underlain by sand, for at least two or three months of the hottest part of the year the ground water of the entire valley is raised by the overflow from the river. Water in wells even back along the mesa is reported as rising and falling with the overflow. From the mesa the land slopes gradually to the overflowed portions, so that only in the lower elevations does the water approach close enough to the surface to cause alarm.

To prevent this accumulation of alkali and remove any excess of alkali now in the soil is a great problem for the farmer of the region. The prevention of further accumulation is all expressed in one short sentence: Prevent the evaporation of water from the surface. If it were well understood that each drop of water carries its little burden of soluble matter (here about 100 parts in 100,000) and that every drop that evaporates leaves behind at the surface of the soil this soluble matter to form the alkali crusts, surely more precaution would be taken to prevent such evaporation. How can evaporation best be prevented? First, by keeping the water table below the reach of capillary action, and second, by shading the surface or maintaining a mulch which will cause a break in the capillarity. The water table may be prevented from rising by using water as sparingly as possible or by proper drainage to carry off the excess. If the crop be one where tillage is possible, much evaporation may be prevented by at all times maintaining a perfect soil mulch, the mulch being renewed from time to time by thorough cultivation. The cultivation should take place as soon as possible after each irrigation, and if water is applied at long intervals the mulch should be renewed between times, for if left uncultivated the soil soon packs and capillary connection is again established. If the crop be one which does not permit of intertillage, as wheat, rye, or alfalfa, then the greatest care should be exercised in leveling to get each portion of the field in condition to be covered by the water in flooding, and in seeding to secure a full stand, which in a short time will effectually shade the surface and retard evaporation. The method of flooding, which is the common practice for alfalfa and small grain, is a great recompense for the inability to cultivate. It can be readily seen that in any system of cultivation and application of water there is of necessity some evaporation from the surface. But when flooding is practiced and the entire surface is covered each time, the accumulation from the evaporation since the last irrigation is washed down into the subsoil, where, if there be movement of the ground water or sub-

drainage, it enters the current and is carried away. Not so, however, in tilled crops and orchards where furrow irrigation is used. Although the orchard or field be ever so well cultivated, yet there will be places between the furrows and in the rows that are never wet directly from the surface, but only by subirrigation, so that whatever soluble matter is left behind from long evaporation is not carried below, but remains at or near the surface, the accumulation soon becoming great enough to injure the plants. So for all tilled crops in a region liable to become alkaline the obvious remedy is occasional complete leveling of the land and surface flooding. Many shallow-rooted, very sensitive trees, such as the orange and the lemon, throughout southern California and Arizona show signs of disease and are suffering simply because water has been applied for a great many years wholly by the furrow method, with a consequent accumulation of alkali. A flooding of these trees would, in many cases, afford almost immediate relief. Much can be done to avoid such injury in this area by carefully avoiding the mistakes made by these early irrigators.

To recapitulate, the following rules should always be kept in mind: Alkali always follows the water. If water continually evaporates from the surface, then alkali will accumulate. To prevent this keep the water table low, at least 6 feet for the loam soils and 4 feet for sand. When land is to be flooded it should be thoroughly leveled, so that all parts will be covered by the water, else the alkali will accumulate on the high places. Tilled fields and orchards should occasionally receive a thorough flooding to wash down the salt left by unavoidable evaporation.

There are other questions of great importance to be considered when farming is begun in earnest, such as the kinds of crops to be grown and the rotation to be followed so that the soils may retain their great fertility. The Colorado River has often been called the Nile of North America. The sediment carried by both these rivers is very rich in plant food, making it well-nigh impossible to impoverish lands irrigated with their waters. Lands along the Nile have been cropped for centuries, and yet when they receive their full quota of rich sediment they produce crops in abundance. The climate of the Upper Nile region and of this Lower Colorado River country are in many ways similar, so that many of the crops which have thrived for centuries in Egypt would no doubt prove profitable here. Already active steps have been taken by the Department to introduce some of these crops. The farmers of this district should do everything in their power to make these introductions a success, as they may mean the difference between success and failure of the agricultural industry for much of this area.

It is on the overflowed part of the valley that especial care should be taken in beginning cultivation and where particular study should

decide the kind of crops to be grown after the complicated problem of reclamation is solved. In clearing the land of native vegetation care should be taken not to allow the land to stand without a covering of some kind unless cultivation is begun immediately. (See Pl. LV.)

The first problem here is the control of the overflow water. Until this water is effectually in hand no farming worthy of the name can be done. To control the overflow it will be necessary to construct a dike or levee along the river, to connect with the mesa land below, of such height and strength as to keep out the river. As has been previously stated, the ground water of the valley rises and falls with the river, and some places are now overflowed 6 to 8 feet. The confining of the river would cause it to rise higher in the channel, so that the ground water over the present overflowed part of the valley would have several feet of head, thus bringing it near to or above the surface. This would necessitate the installation of a drainage system, with a pumping plant at the lower end of the valley to lift the water above the levee and back into the river. This leveeing and draining would be expensive, but since the subsoil is usually quite porous the drains need not be close together, and the natural fertility of the soil, together with the advantages of abundant water and almost tropical climate, would certainly make such reclamation a paying investment.

The date palm is generally conceded to be the crop which, by long cultivation in a similar region in Africa, has become peculiarly adapted to the soils and climate of such an area as this. Date palms will thrive in soil having as much as 3 per cent of alkali. Experiments are now being carried on in the Salt River Valley to test the Algerian date palms in Arizona, and the present season some experiments will be made with Egyptian cotton in the Colorado delta. Other crops from parts of the globe with a similar climate should be tried until a new agriculture, consisting of crops which it is impossible to grow in the colder parts of the United States, shall be developed. Such an industry should yield to the farmers a revenue far greater than that now derived from the almost exclusive growing of alfalfa and the raising of stock.

LANDS, SHOWING DENSE GROWTH OF WILD HEMP, YUMA AREA, ARIZONA.

This is the character of land now being taken up for irrigation.

G A DENSE GROWTH OF MESQUITE, SCREW BEANS, AND WILD GRASSES, ADAPTED TO PASTURAGE, YUMA AREA, ARIZONA.

his is the character of lands now being taken up for irrigation.

A Well Established Alfalfa Field in the Yuma Area, Arizona.

In the foreground is an adobe hole for the watering of cattle.

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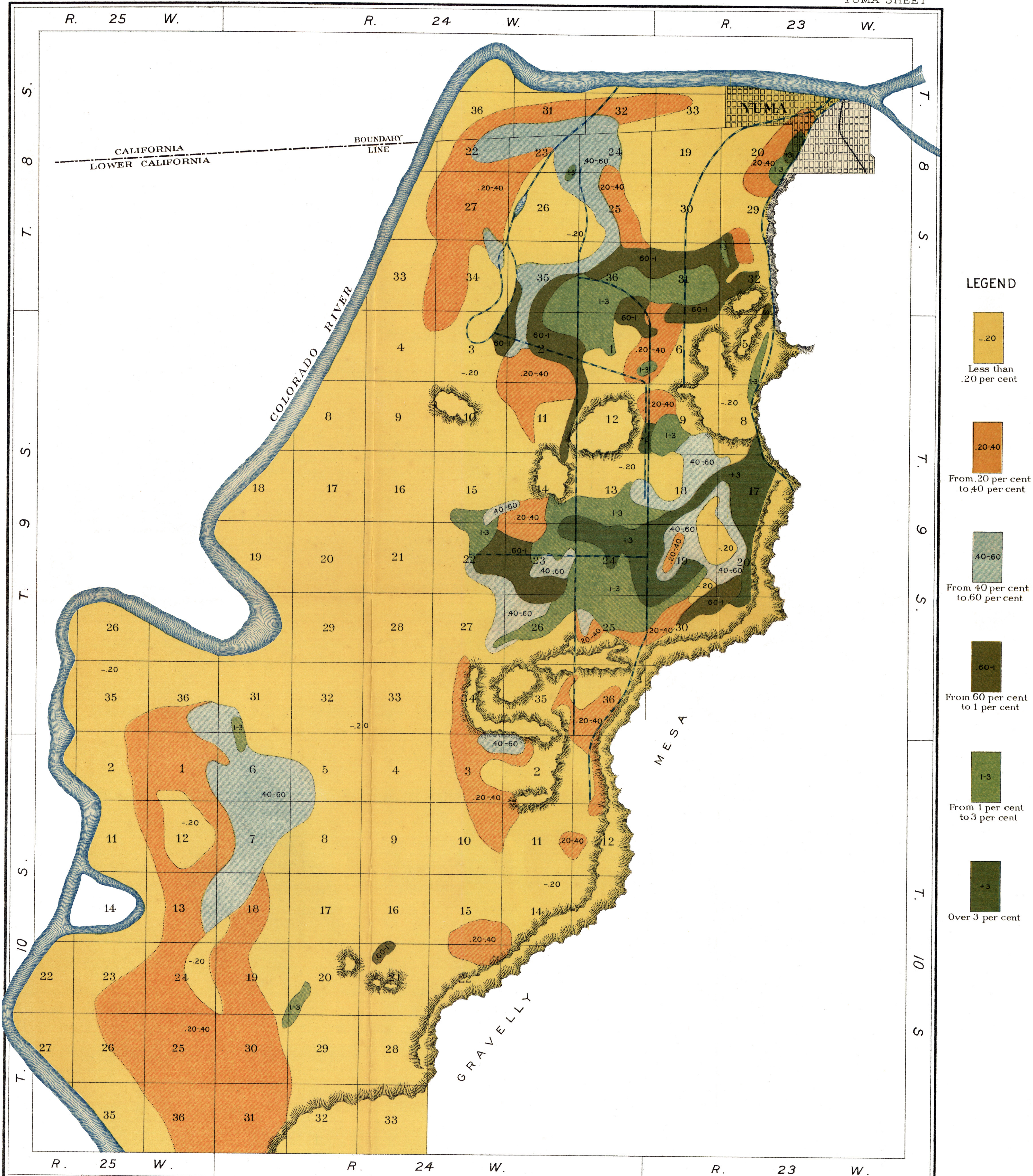
ALKALI MAP

ARIZONA
YUMA SHEET



Alkali Surveyed by
J. Garnett Holmes and B. A. Olshausen.
1902.

Scale 1 inch = 1 mile

Field Operations
Bureau of Soils
1902.

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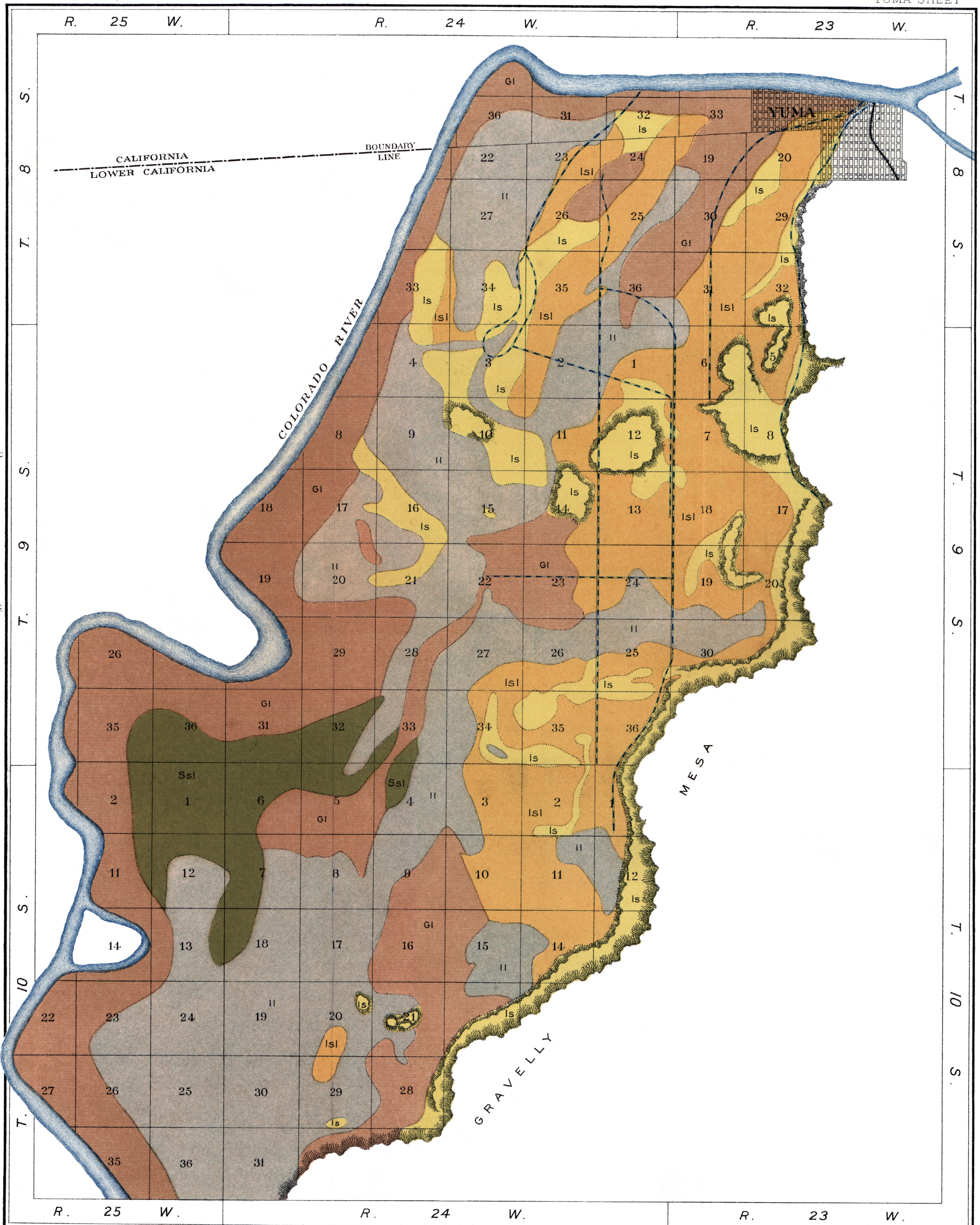
SOIL MAP

ARIZONA
YUMA SHEET



Soils surveyed by
J. Garnett Holmes and B. A. Olshausen
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Scale 1 inch - 1 mile

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